Local opportunities and innovative behavior. A meta-analytic study on European cities

Nijkamp, P.; Kangasharju, A.; van Geenhuizen, M.

1997

document version
Early version, also known as pre-print

Faculteit der Economische Wetenschappen en Econometrie

Serie Research Memoranda

Local Opportunities and Innovative Behaviour: A Meta-Analytic Study on European Cities

Peter Nijkamp
Aki Kangasharju
Marina van Geenhuizen

Research Memorandum 1997-72

December 1997

vrije Universiteit amsterdam

LOCAL OPPORTUNITIES AND INNOVATIVE BEHAVIOUR:

A META-ANALYTIC STUDY ON EUROPEAN CITIES

Peter Nijkamp
Department of Regional Economics, Free University of Amsterdam, The Netherlands, pnijkamp@econ.vu.nl

Aki Kangasharju
School of Business and Economics, Research Center, University of Jyväskylä, Finland

Marina van Geenhuizen
Faculty of System Engineering, Policy Analysis and Management, Deeft University of Technology, The Netherlands

Abstract
This paper addresses the issue of technogenesis and investigates in an exploratory way whether local factors are important for innovativeness of firms. Particular attention is given to the knowledge base of cities. The paper aims also to model effects of relevant local factors on innovativeness of firms by means of logit analysis and a qualitative impact approach based on the recently developed rough set analysis. Cities in three European countries are considered. Our empirical results from these cities show, first, that local factors are more important for more innovative than less innovative industries and more important for product than process innovations. Assuming a product life cycle path, these results imply that the evolution of the importance of local factors for innovations reflects a distinct time path. Second, among more than 20 local factors, the interviewed firms appear to consider support measures for skills training particularly important for innovations. Accordingly, the results of our logit models reveal that in particular skills training links with a local university contribute significantly to the propensity to innovate.

Keywords: innovativeness, life-cycle, incubation, logit model, rough set analysis

1. The Critical Role of the Urban Milieu

Science and technology are often regarded as competitive weapons of cities or regions. Consequently, the interst in dedicated science and technology initiatives which aim to stimulate urban and regional economies is increasing. The growing role of knowledge in wealth creation at the urban and regional level is more and more recognized (see Van Geenhuizen and Nijkamp, 1996a and 1996b; and Gibbons et al., 1994). There is, however, also an increasing awareness that knowledge creation needs specific urban or regional breeding place conditions, and - as a consequence - presently the critical role of urban and regional milieus and cultures in knowledge development is increasingly coming to the fore (see Florax, 1992; Van Geenhuisen et al., 1996a and 1996b; and Lambooy, 1996).

The above breeding place hypothesis presupposes that the process of knowledge development is not uniformly distributed over space, but is contingent on specific locational and local conditions, which may concern the availability of venture capital, access to advanced communications and transportation infrastructure, presence of research facilities and so forth. Many of these conditions are met in cities (or urban areas), which explains why such areas are prominent places for technological innovation and incubation (see Charles and Howells, 1992; Davelaar, 1991; and Williams and Gibson, 1990). In addition, thare is the clear tendency that modern industries are becoming, on the one hand, more science-based and knowledge-intensive and, on the other hand, increasingly oriented towards urban areas regarding their management and research function. These areas are able to influence positively their future development, as many business activities in a post-industrial era tend to become sensitive to the urban milieu and urban quality of life. At one level globalization means a levelling of access to new knowledge and technology, such as through the spread of electronic networks and databases. Accordingly, urban areas are losing their advantage of knowledge producing localities. However, at another level particular uncertainties in management and research can only be reduced in specific urban regions with excellent knowledge resources and learning capacity (Amin and Thrift, 1994; Van Geenhuizen and Van der Knaap, 1997; and Kanter, 1995). This capacity is based on knowledge that is created and released locally but also on connectivity with sources of knoledge somewhere else in the world. The recent shift to knowledge-based and information-oriented urban areas takes place because of the network externalities, the abundant knowledge resource and incubation potential of these areas. Thus, knowledge, science and technology are likely to become primary forces driving development towards and orientation to the urban milieu, which is marked by creativity, synergy and innovation (see Camagni, 1991).

In a recent study by Van Geehuizen et al. (1996b) is argued that the urban knowledge capacity is a major accet in the economic competitive power of cities. This knowledge capacity comprises essential activites in the urban space, leading to several scale and scope advantages, notable (see FAST, 1992):

- new research and development (R&D) results (including product innovation)
- new research methods (hardware and software) (including process innovation)
- new dissemination and marketing channels for research products (or innovations)
- new ways of organizing and managing R&D.

In the same FAST document it is argued - and empirically demonstrated on the basis of a large sample of European cities - that the local availability of a knowledge and information pool (e.g. skilled staff and scientists) is critical for the production of new R&D results, followed by availability of land and buildings, local suppliers of equipment, and presence of local financial institutions. A more detailed analysis of the local knowledge and information pool brought to light that several local factors are important here: skilled labour, training support for researchers, presence of libraries, presence of conference facilities, availability of local cooperation partners, local subcontractors and management links with local educational facilities.

In conclusion, modern cities have the opportunity to act as major islands of science-based innovations through the use of local networks offering local economic synergy and through the connectivity with (inter)national information and communication networks. Further empirical evidence on the relevance of the 'local milieu' for future innovations activities of European companies can be found in Figure 1. Most notable is the overwhelming importance for European firms of labour market skills and training support regarding all four types of innovation. This is followed by local synergy from suppliers, subcontractors, customers, and universities for product innovations, and connectivity advantages (through telecommunication and transport) regarding other types of innovation.

Clearly, it is also evident that several cities have major deficiencies in the supply of the above success conditions. For example, several firms mention lack of office space as a major bottleneck. Also local support (e.g. contacts with the local public sector and the attitude of local politicians towards the R&D sector) are usually regarded as major impediments (see again FAST, 1992). In general, access to local and international transport and telecommunication networks appears to be a top-priority urban policy concern. The FAST dossier then concludes that there is need for action.

"All cities in the New Europe will have to come to grips with the fact that economic welfare will depend on the establishment of an integrated system of creation and transfer of scientific knowledge as the knowledge content of goods and services is rising. Income opportunities of citizens and the public sector will critically depend o the innovation potential of cities. Enhancing the milieu as a necessary condition for such a potential to materialize becomes a top priority task. I will require a multilevel approach as the milieu is the result of actions by many decision-making units in the private and public sector".

Although it has to be recognized that in particular modern information and communication allow in principle for a rapid diffusion of scientific knowledge, in reality many innovative activities are rather centrifugal as far as their invention, development and management is concerned. Consequantly, we observe concentration and deconcentration tendencies at the same time. Clearly improvement of knowledge networks at a wider scale than the metropolitan level would be needed to sope with the problems of peripherality and of the social-geographical exclusion.

2. Local Dynamics and Innovativeness

Regional and local dynamics depends to a large extent on entrepreneurial innovation. Besides, intrinsic regional features may affect innovativeness of firms within a given region, in addition to the different engagement of these firms in the development of new technologies and processes. Thus, on the one hand, the region's innovative activity is determined by R&D activity, size, market power, industry, and phase of the 'industry-technology' life-cycle of firms located in the region (see Ormrod, 1996 and Love et al., 1996). On the other hand, regional characteristics affect the innovative activity of firms by enhancing or inhibiting the effects of innovative inputs of firms in the region. Davelaar (1991) coins these factors as production structure and 'production milieu' components, respectively. Consequently, firms which are located in different regions, but have identical innovative inputs, may have different innovative outputs resulting in differing innovativeness of regions (see Figure 2). According to Camagni (1991), the local (innovative) milieu may enhance innovativeness and thus growth of firms, if it reduces the intrinsic uncertainty of the innovation process concerned. Clearly, there is a complex array of factors determining local economic dynamics.

A fairly comprehensive analysis of spatial aspects of innovation has been given by Davelaar (1991) who distinguishes four groups of local factors which affect local innovativeness: (A) agglomeration economies which include location economies accruing from the presence of the same industry, and urban economies accruing from the presence of different industries; (B) demography and population structure which refers to local resources of human capital, local customers and size of the local market area; (C) availability of specialized information and intensive communication networks (information infrastructure) including also educational institutes; and (D) social overhead capital (physical and institutional infrastructure) which responds faster to new demand for technological systems in central areas than in the periphery and which requires various local institutions and physical infrastructure (see also Davelaar and Nijkamp, 1997). These force fields are mapped out in Figure 2. We will translate some of the major linkages from Figure 2 in four testable hypotheses in an empirical setting.

It needs to be mentioned that the critical role of the so-called 'production milieu' can also be interpreted in a different way. Advocates of the 'innovative milieu' school argue that, in addition to infrastructural factors, human capital, (mainly) informal linkages between firms in a region and synergy effects from a common cultural, psychological and political background are decisive

(Camagni, 1991). In other words, this school emphasizes more the synergy effects, which promote a collective learning process and reduce dynamic uncertainty, than Davelaar's static local factors, like infrastructure, which reduce transaction costs and produce external economies (see also Gertler, 1996 and Harrison, 1996).

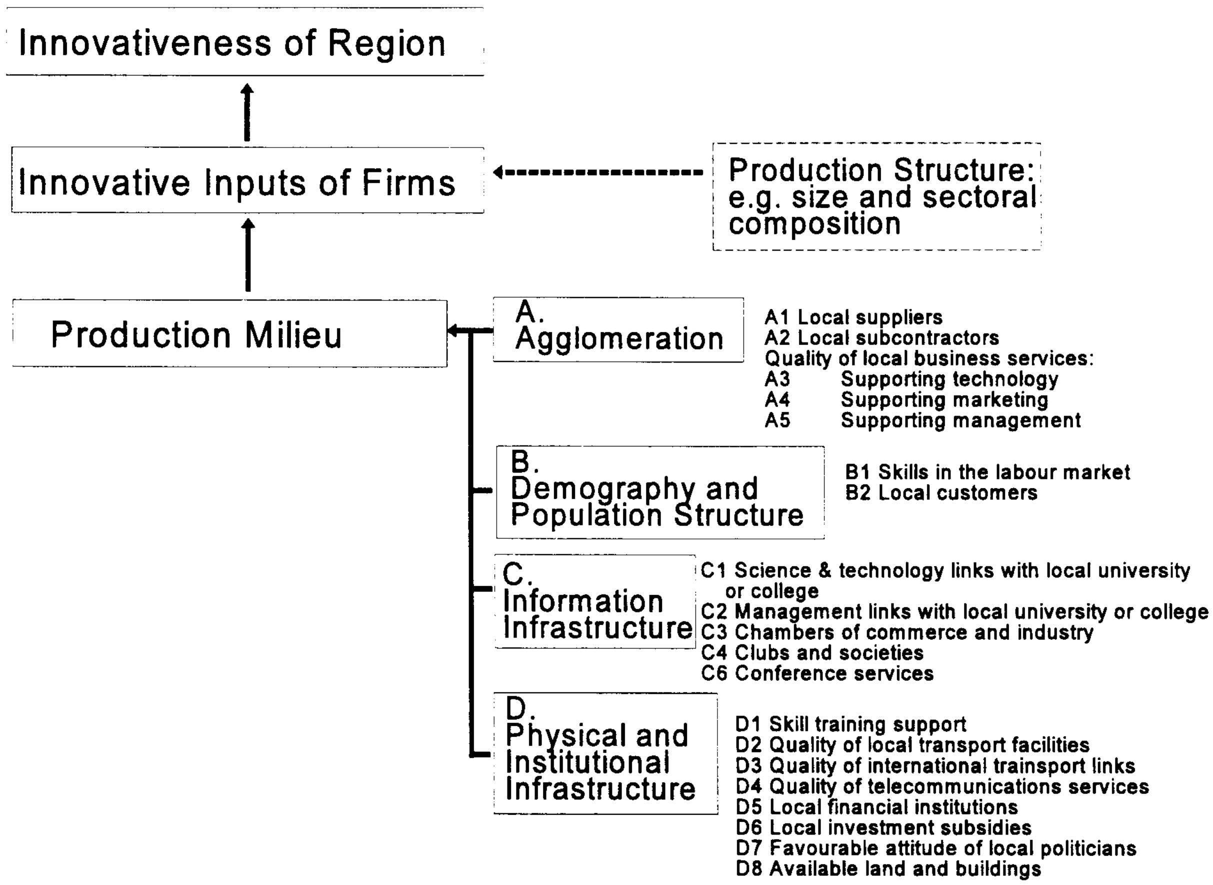

Figure 2. Operational Variables for the Four Groups of Explanatory Local Factors (A-D)

The importance of local resources of human capital results from the fact that it tends to stimulate local collective learning processes, because labour is more mobile within a region than between regions. Boschma (1994) argues that local education and research facilities contribute to this local accumulation of skills and knowledge, because producers gain when at least part of the costs of job training as well as basic R&D are carried out by such institutions specialized in knowledge acquisition and transfer.

Furthermore, Camagni (1991) emphasizes the importance of informal linkages both between firms and within various economic actors such as firms, employees and institutions. Local formal and informal networks between firms, which are essential in the acquisition of the latest technology, will likely lead to lower information gathering costs. Local institutions are important parts of local networks, because they overcome market imperfections which inhibit innovative behaviour. The development of collective knowledge as well as formal and informal linkages between suppliers of labour, capital and institutions contribute to a regional identity and culture, which may result in a desire for cooperation. According to Camagni (1991), common cultural roots are important in the formation of tacit knowledge in order to understand and use complex messages and in the formation of commonly accepted beliefs in new products and technologies in a given area.

Our previous observation on the role of uncertainty in innovative behaviour may lead to our first testable hypothesis. Because process innovations enhance the use of existing products, the uncertainty is lower here, and thus the role of local factors tends to be smaller. Therefore, the first hypothesis is:

H_1: *local factors are more important for product than for process innovations.*

It should be noted that in the standard approach to the analysis of technological change, the innovation model has essentially three stages: (i) basic research produces a scientific or technological discovery; (ii) creative firms develop this invention towards a new product; (iii) and exisiting firms apply this product for commercial use. Through market reactions, successful commercial use has feedback effects on scientific basic research as well as on R&D efforts of firms (see e.g. Kline and Rosenberg, 1987). Davelaar (1991) argues that such a change in science and technology leads to major inventions and basic innovations which, together with socio-institutional and economic forces, form a new technological system whose occurrence may be discontinuous in time. Dosi (1988) emphasizes the importance of basic research from the viewpoint that the progress in scientific knowledge widens the pool of potential technological paradigms (or technological systems) from which only a small set of paradigms is actually developed. New technological systems, which happen to emerge, give birth to new technological trajectories or sequences of innovations, along with a swarming process of (new Schumpeterian) firms producing further product and process innovations with a decreasing marginal product. A good example of such a technological regime (or system) is the micro-electronics industry which has been built up around such major innovations as the transistor (Boschma, 1994). These swarming processes along technological trajectories form life-cycles for technologies and industries. In essence, this approach is closely related to the well-known spatial product-life cycle approach developed by Vernon (1966). When adjustments and innovations within existing systems become rare and marginal, new technological systems or regimes will eventually replace the old ones. Therefore, our second hypothesis is related to this life-cycle approach so that economic dynamics is introduced.

At the beginning of an industrial life-cycle firms produce numerous early (and often significant) innovations, which are mostly product innovations and which are encouraged by the technological push of a scientific basic invention. Products are then not yet standardized, which means that the uncertainty concerning market reactions is high. Innovations during this phase put specific demands on the surrounding business environment. Information concerning unstandardized products, market reactions and skills on the labour market in terms of producing and developing these new products are important conditions for a successful innovation. In a later stage, when main products within the new industry have been established and when they are becoming more standardized, the role of business environment may decline. Therefore, our second hypothesis to be tested is:

H_2: *local factors are more important for a (more innovative) younger than for an (less innovative) older industry.*

Clearly, this hypothesis is plausible, because younger industries tend to produce more product innovations than older ones. On the one hand, local factors are more important for product than process innovations for the reasons mentioned above. On the other hand, new product innovations tend to become more marginal during the later phases of industrial life-cycle, while process innovations tend to become more wide spread. Product innovations loose importance over time, as product innovations cannot be created endlessly within one and the same technological system. Process innovations will then gradually take over, because when further product innovations are increasingly hard to create and when products become more standardized, firms try to develop better production processes to ensure or enhance their competitiveness. Thus, free market competition is a driving force.

It is of course true that local factors are not equally valuable. And therefore, we will also study more carefully the subset of local factors, which appear to act often as critical success conditions for entrepreneurial innovations. Such a more detailed analysis will be carried out in order to model the effects of this subset of local factors (production milieu) on innovativeness of firms. The impact of the 'production milieu' in empirical research is not always very significant. Davelaar (1991) argues that after controlling for the industrial structure, there is limited evidence for a positive impact of the urban 'milieu' on innovativeness of firms. This statement however, may be questioned and should at least be further investigated and tested. Therefore, the third testable hypothesis in our series is:

> H_3: *the local 'production milieu' has a positive impact on innovativeness of firms in the area concerned.*

Having specified three hypotheses to be tested in an applied context, we will now proceed by describing the data base for our empirical work.

3. The Data Set: Description and Exploratory Analysis

The hypotheses of our study require information on the micro level of firms. The data set used in our empirical work stems from the co-called URBINNO[1] study and has been compiled by extensively interviewing many manufacturing companies in the United Kingdom (208 firms), the Netherlands (33) and Italy (32). Interviews on a structured basis were held among firms in different manufacturing industries in different cities. For practical reasons, the empirical investigation in our study is mainly concentrated on those industries which have for the sector concerned a sufficient number of observations. These are: manufacturing of machinery and equipments (SIC 29); electrical machinery and apparatus (SIC 31); medical precision and optical instruments, watches and clocks (SIC 33); and motor vehicles, trailers and semi-trailers (SIC 34). In addition to these sectors, our empirical investigation is also dealing with two other, aggregate sectors in order to have a sufficiently large data base, viz. textile, wearing and leather industries (SIC 17, 18 and 19 taken together), and basic materials and metal industries (SIC 27 and 28). This seems a plausible approach, because the latter industries are sufficiently close to one another to benefit likely from the same source of technological development, so that they are likely to live on the same technological trajectory. The urban background of innovative behaviour has been given due attention in the interviews, in the sense that a systematic typology of cities in all the countries concerned is made.

We have adopted the most straightforward measure of innovativeness (see Harrison et al., 1996); innovativeness of industries in a city is measured by calculating the percentage of firms that has adopted an innovation during the past few years. The frequency of these firms is given in Figure 3. These results indicate that 39.9 percent of the total of 273 firms mentioned an innovation in the

---

[1] The URBINNO group ("Urban Innovation") was a network of researchers in several European countries. The objective of the group was to study innovations in several urban areas from various points of view, viz. population, urban economy, institutions and infrastructure, and from a micro-urban (i.e., firm level) perspective.

sense defined above. At a two-digit level, industry 34 turned out to be the most innovative, as 77.3 percent of the firms in that industry mentioned an innovation. In contrast, in the industries 27-28 together only 29.0 percent mentioned an innovation, while this figure was even down to 21.1 percent for the firms in the industries 17-19. There are thus quite some variations in outcomes, and it is therefore interesting to seek for a spatial bias in these outcomes.

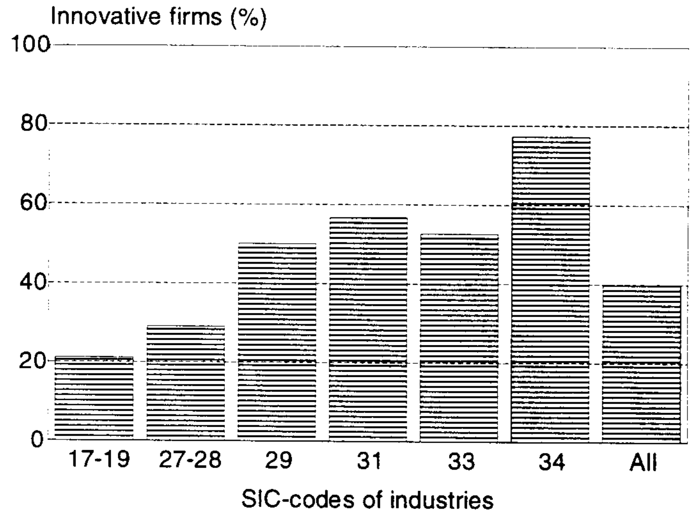

Figure 3. Innovativeness of Firms by Industry Classes

We will now first present some exploratory results from a descriptive analysis of our data set. To begin with, our two first hypotheses (H_1 and H_2) on the importance of the local 'milieu' will be tested by means of exploratory background variables derived from Davelaar's (1991) classification into four local factors (see for details Figure 2 above). The lists of specific local factors under the four headings are examples of factors whose presence will plausibly contribute to the innovativeness of firms in the region. The factors distinguished in Figure 2 are the ones included in above mentioned URBINNO questionnaire. Given a set of individual firm data, the importance of local factors for product and process innovations will be tested. Figure 4 shows the results for all industries together. This figure includes only those 11 local factors which the respondents considered commonly as valuable factors in terms of either product or process innovations.

According to the firms surveyed, local factors are more important for product than for process innovations. There are only two exceptions: 'Management links with local university or college' (C2) and 'Quality of local business services supporting technology' (A3) are more important from the point of view of process innovations than from that of product innovations. Hence, our overall result suggest that the firms in our sample behaved in accordance with our first hypothesis (H_1). The results also indicate that local skills in the labour market (B1), and local skills training support

(D1) are the most important local factors. It appears that 48.6 percent of the firms considers skills in the labour market as of 'some importance' or of 'major importance' for product innovations, while 36.1 percent of firms does so for process innovations. The respective numbers concerning training support are 41.4 and 36.1 percent. From an in-depth analysis among medium-sized firm in the Netherlands it appeared that the strong labour market concern delt with the following three fypes of attributes: (1) shortages of certain handicraft skills, (2) shortages in skills to apply modern technology in traditional fields, such as informatics in textile industry, and (3) a general shortage of practical skill of youn people who complete vocational anc academic training (Van Geenhuizen and Nijkamp, 1996a). Clearly the latter two point to a potentially impotant role of local universities. The quality of telecommunications services (D4), local suppliers (A1) and science and technology links with universities (C1) are the next important factors.

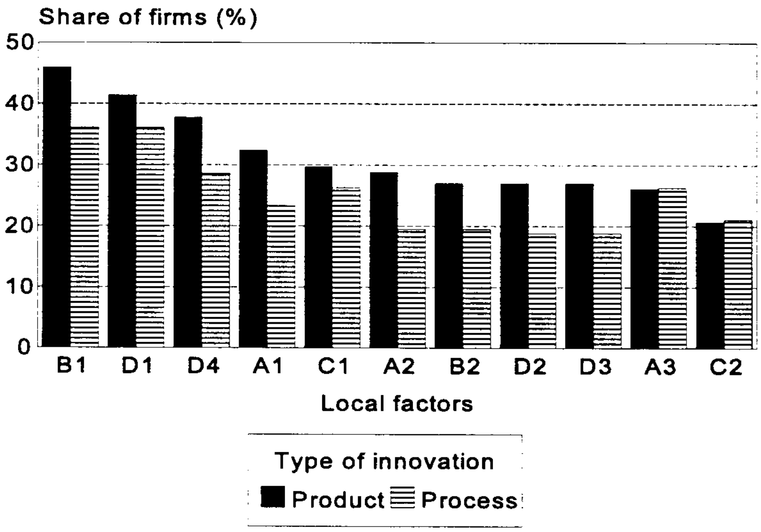

Figure 4. Percentage of Firms who Consider Local Factors Important for Innovations

The above results imply that firms can apparently benefit from cooperation with a local university, because certain links with the local university would improve those local breeding place factors which were mentioned most commonly as important among the firms surveyed (see also Van Geenhuizen and Nijkamp, 1995b). For instance, the second important local factor, i.e. 'Training links (D1) with local universities', supports the most important local factor, i.e. 'Skills in the labour market' (B1); and a nearly as important factor, viz. 'Science and technology links with university' (C1) enhances knowhow. Both factors would be possible candidates to promote innovativeness of firms. The role of university links of firms for innovativeness will be further examined by using a logit and rough set analysis below in Subsections 4.1 and 4.2, respectively.

Figure 5 presents the results for the selected industries, for example, firms in less innovative industries, SIC 27-28, appear to consider local factors as less valuable than firms in more innovative industry classes (industry 34). The results clearly show that the local factors are more important for the more innovative (younger) industries than for the less innovative (older) industries.

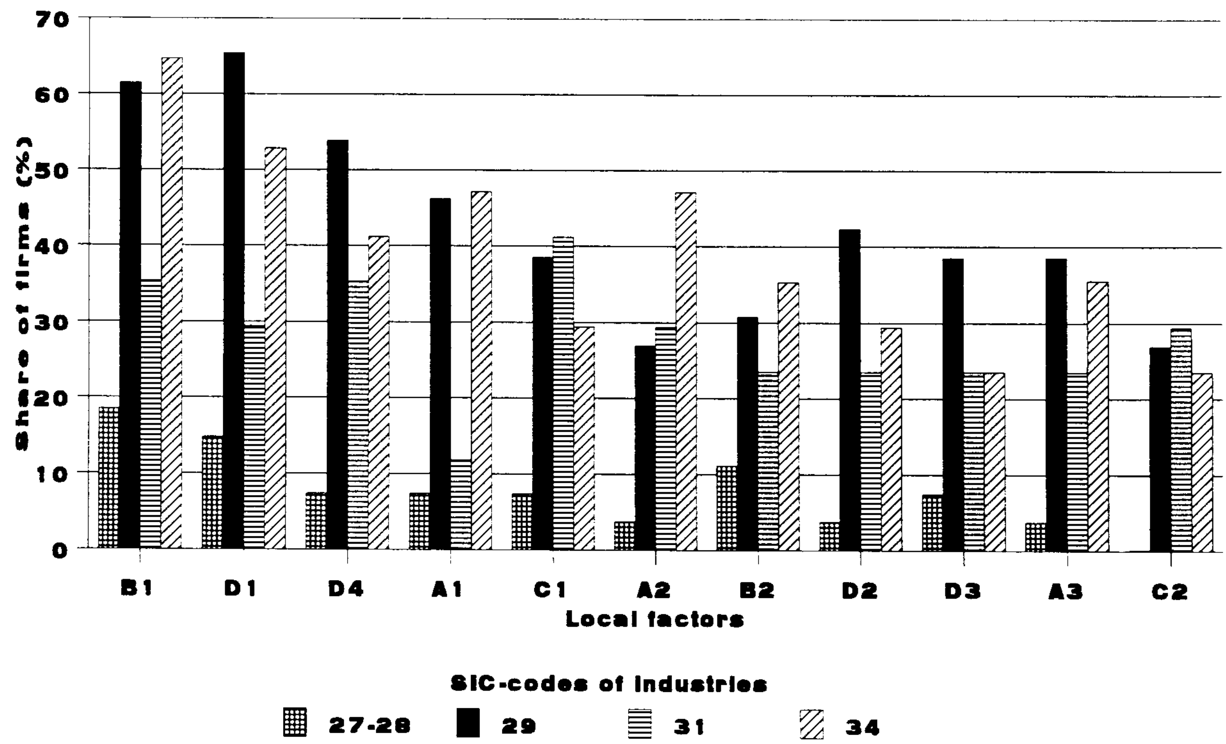

Figure 5. Percentage of Firms in Different Industries who Consider a Local Factor as Important for Innovations

Figure 6 presents the results for a classification of industries (this classification was made according to industrial innovative behaviour). The black bar represents highly innovative and the bar with streaks low innovative industries (57% of firms in the highly innovating industries mentioned an innovation in contrast to only 18% of firms in the low innovating industries). Local factors are clearly more often important for highly innovative than for low innovative industries. Therefore, these results indicate that - regardless of the classification used (high or low innovative industry, different industries) - there is a structural tendency that the more firms innovate the more important local factors are. Clearly, these results support our second hypothesis (H_2).

So far we have been investigating how firms in different industries value local factors in terms of innovations. The exploratory analysis did not reveal, however, whether or not local factors actually affect innovativeness of firms, i.e. so far we have not tested our third hypothesis. This is the subject of the next section.

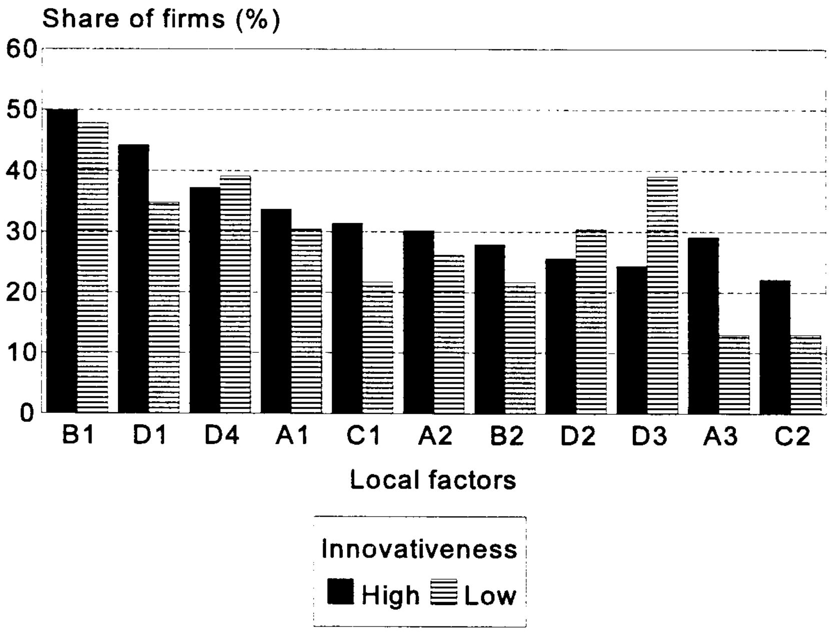

Figure 6. Percentage of Firms in Two Categories who Consider a Local Factor as Important for Innovations

4. Explanatory Analysis

4.1. Logit analysis

We will now offer an explanatory analysis for the firm's innovative behaviour by applying a logit analysis. We will model innovativeness by industrial and production milieu variables in order to test our second and third hypotheses. Logit analysis cannot be applied to testing of our first hypothesis, because our data set does not include separate measurable variables for product and process innovations.

In our data set on industrial attributes only 0-1 categorical variables are available. For various modelling purposes we have altogether 13 dummy variables in our data set. In the present context, the most interesting variables are of course industrial and urban 'milieu' variables. Variables which begin with IND... (e.g. IND1719DUM) are dummies for the 6 selected industries. The urban 'milieu' variables mainly represent those local factors, which were commonly found to be important among firms surveyed, viz. various links of firms with local institutions. A variable which begins with LINK... is one of the 3 dummies for the industries which have commercial (LINKCOMM), training (LINKTRAI) or recruitment (LINKRECR) links with a local university or college. The possible impact of commercial (consultancy, testing, subcontracting, joint ventures) and training links is more easily justified than that of recruitment links, because they directly correspond to two commonly and highly valued local factors, viz. 'Skills training support' and 'Science and technology links'. Nevertheless, we do not wish to exclude the dummy for recruitment links a priori. ASSTRAIN is the dummy for firms which have received training assistance from a local (or regional) public sector institution or agency[2].

We will first model the propensity to innovate by using all 13 dummies which reflect industrial structure, location, or local factors. We will use here Theil's sequential elimination procedure, by discarding one redundant variable at a time from the equation beginning with the most insignificant variable (Theil, 1971). This reduction procedure will be continued until only statistically significant regressors are left in the explanatory model.

The above described procedure leads to the statistical results shown in Table 1. These results imply that the relatively more innovative (younger) industries contribute significantly to the propensity of a firm to innovate. The less innovative (older) industries do not contribute to the innovation propensity. We recall here that SIC-industries 17-19 and 27-28 are less innovative and that 29, 31, 33, and 34 are more innovative industries. This result was also found in the exploratory analysis.

Table 1. Innovation as Dependent Variable in a Logit Analysis

-2 Log Likelihood: 367.30157 (restricted model)
-2 Log Likelihood: 323.413 (full model)

-Variable-	B	S.E.
IND29DUM	1.0613	.3427
IND31DUM	1.2892	.4229
IND33DUM	1.2720	.5115
IND34DUM	2.0964	.5507
LINKTRAI	.9312	.2799
Constant	-1.6011	.2635

Note: B=estimated coefficient and S.E.=standard error

[2] Due to an incomplete data set, our logit analysis had to exclude a few indicators on production structure which may be expected to affect the propensity to innovate (such as size, market power and growth rate of a firm).

Training links appear to be positively related to innovativeness, but commercial or recruitment links are not (see Table 1). This indicates that at least such local factors as training links with a local university tend to contribute to innovations, a result which partially supports our third hypothesis (H_3). This also complies with the above obtained results that 'milieu' factors, which affect innovativeness of firms, are not equally important. In particular, this result is in line with the previous finding that firms regard skills training support more often as an important local factor inducing innovations than science and technology links (commercial links) or managerial links with the local university. It also turns out that training support from other local or regional institutions is not a statistically significant regressor either. This implies that skills training support offered by a university tends to be more important than that offered by other skills training institutions.

A related question is now for which industries the most important factor, viz. training links, contributes to innovativeness. It is also an important question whether the other links (commercial and recruitment) contribute to innovativeness in any industry. In other words, we are interested in finding out a possible confirmation for our second hypothesis and further support for our third hypothesis. We can partially test these hypotheses by distinguishing the firms within each industry into two classes, viz. those with a link (LINKTRAIN, LINKCOMME and LINKRECR) and those without a link (LINKTRNO, LINKCONO and LINKRECNO). This subdivision is made for all three links, namely training, commercial and recruitment links. After the model reduction procedure described above the estimation results are given in Table 2. This table prompts us to make the following comments on the results.

Table 2. Innovation as Dependent Variable in a Logit Analysis

-2 Log Likelihood: 367.302 (restricted)
-2 Log Likelihood: 310.698 (full)

-- Variable --	B	S.E.
IND33DUM*LINKTRAIN	3.0709	1.0717
IND29DUM*LINKTRAIN	2.4603	.5762
IND34DUM*LINKCOMM	2.1981	.6776
IND34DUM*LINKCOMNO	2.2469	.8177
IND31DUM*LINKCOMM	1.6873	.5708
IND29DUM*LINKRECRU	-1.7174	.8552
Constant	-.9942	.1608

The firms in the industries 29 and 33 with training links appear to innovate more often than the firms in the other industries with training links and the firms in the same industries without training links (see Table 2). This implies that training links are more important for the relatively more innovative (younger) than for less innovative (older) industries, and thus gives partial support to the second hypotheses. In addition, the firms in the industry 31 with commercial links tend to innovate more often than the firms in other industries or in the same industries without commercial links. On the one hand, firms in industry 34 with commercial links appear to be more innovative than firms in other industries with commercial links and firms in the same industry without commercial links. On the other hand, also an opposite result is found: firms in industry 34 without commercial links turn out to be more innovative. These results imply that commercial links would not play a decisive role in the motor vehicle industry (34), but would certainly play a role in the electronics industry (31). Nonetheless, this implies that also commercial links are more important for the relatively younger than for older industries, which also renders partial support to the second hypothesis. Also the third hypothesis is partly supported by these results, which indicate that such local factors as training and commercial links with a local university influence the innovativeness of firms.

Table 2 also shows that firms in industry 29 with recruitment links tend to innovate less often than firms in other industries with such links and firms in the same industry without recruitment links. This does not seem to be the case for other industries. These results tend to suggest that for one of the younger industrial sectors the recruitment links would have even a negative effect on innovativeness, a finding which implies a low importance of rercuitment links for innovativeness. Despite the latter observation our statistical results seem to largely confirm our two hypotheses.

4.2 Rough set analysis

A limitation of the analysis in Subsection 4.1 is the large number of categorical (binary) variables. Now we will seek some further evidence for the importance of the production milieu for innovativeness of firms (H_3) by applying rough set analysis. Rough set analysis is a fairly recent classification method of an 'if-then' nature (see e.g. Pawlak, 1991; and Slowinski, 1993)[3]. The analysis classifies objects into equivalence classes using available attributes which act as equivalence relationships for the objects considered. Objects in the same equivalence class are indiscernible (indistinguishable). A class which contains only indispensable equivalence relationships (attributes) is called a core. An attribute is indispensable if the classification of the objects becomes less precise when that attribute is left out. The values of the attributes of all objects may be subdivided into condition (background) and decision (response) attributes.

[3] Formally, a rough set is characterized by the feature that it is not possible to tell a priori which objects belong to a given set, although it is in principle possible to identify all objects which may belong to that set (see for details, Van den Bergh et al., 1997, and for several applications e.g. Baaijens and Nijkamp, 1997).

The aim of rough set analysis is usually first, to classify decision attributes on the basis of condition attributes and second, to form decision rules which are implication relationships between the description of the condition attributes and that of decision attributes. Decision rules can be seen as conditional statements of an 'if-then' nature. Rough set analysis basically evaluates the importance of attributes for a classification of objects, reduces all superfluous objects and attributes, discovers most significant relationships between condition attributes and objects' assignments to decision classes, and represents these relationships e.g. in the form of decision rules (Slowinski and Stefanowski, 1993). Rough set analysis is clearly very appropriate in case of qualitative or categorical statements obtained in interviews. Therefore, we will apply rough set analysis for our empirical work on the background factors of innovative behaviour.

In our rough set analysis a total of 273 firms appear to act as indiscernible objects. The decision attribute (dependent variable) is here whether or not a firm has innovated. Our investigation will focus on those condition attributes (local milieu factors) which in the above exploration turned out be the most important. The condition attributes (explanatory variables) are the following: 1) industry (SIC industries 17-19, 27-28, 29, 31, 33, 34, and the class 'rest'); 2) training links (yes, no); 3) commercial links (yes, no); 4) recruitment links (yes, no) with a local university; and 5) assistance (investment, training, or other) given by a local or regional institution[4]. Production milieu variables (2-5) represent important local factors, i.e., various links of firms with local institutions (see Figure 2).

As shown in the first row in Table 3, the condition attributes appear to allocate 69 firms to the class 'innovation' and 126 firms to the class 'no innovation' (lower approximations). This means that out of the total of 273 firms, 71.4 percent firms can be classified to either the innovative or the non-innovative category. An interesting rough set result is that all condition attributes turn out to belong to the core. In other words, there are no redundant attributes, which means that an exclusion of one of these features would reduce the accuracy of classification. This result tends to show that both the production milieu and structure are important attributes of innovativeness. With regard to production structure, however, we need to make a restriction. The production structure is only an important attribute when the industry sectors involved are significantly overrepresented in the urban areas under study.

[4] The analysis also included variables for areal categories (central, intermediate, and periphery) and competitive edge (innovativeness; cost-effectiveness; and marketing, financing, or other). The results for those variables are given in Kangasharju and Nijkamp (1997).

The relative importance of the attributes can be investigated by dropping at a time one of the attributes from the core. The lower rows in Table 3 show the number of classifications and the quality (percentage) of classifications when each attribute is excluded in turn. The second row indicates that when the attribute 'Industry' is excluded, the quality of classification is the lowest; then, only 30.4 percent of the firms can be classified. The quality of the classification decreases the least when the attribute 'Recruitment links' is excluded. Then, even 65.6 percent of the firms can still be classified. Although link attributes (milieu variables), namely training, commercial, recruitment and assistance attributes, tend to be less important than the others for the proper classification of the firms in terms of innovativeness, they belong yet to the core and are necessary for a high quality classification. In other words, the above rough set results clearly indicate that production milieu tends to affect the innovativeness of firms in a region, a finding which supports our third hypothesis (H_3). Thus, we may conclude that also rough set results tend to confirm our prior expectations laid down in three hypotheses.

Table 3. Lower Approximations for Rough Set Classes

N=273	Innovation	No innovation	Quality of classification
Classification with core attributes			
	69	126	0.714
Classification with a temporarily reduced condition attribute			
Industry	26	57	0.304
Training links	60	104	0.601
Assistance	56	110	0.608
Commercial links	56	112	0.615
Recruitment links	61	118	0.656

5. Concluding Comments

Our industrial society is increasingly moving towards a knowledge society, characterized by close links with R&D and educational centres. The present study has investigated the importance of local factors on innovativeness. Empirical results for the importance of local factors supported the three main hypotheses specified. The exploratory analysis produced some evidence that local factors are considered as more important for product than for process innovations and that they are more important for more innovative, younger industries than for less innovative, older industries. We also saw that a possible cooperation of firms with a university may incorporate those factors, which were most commonly mentioned as important, viz. skills of the labour force by training links, and science and technology links. The logit analysis revealed that among those links with universities, especially training links tend to promote more innovativeness than commercial or recruitment links, a result which leads to a policy recommendation on the significance of increased schooling and training expenditures. Both rough set and logit analyses produced also some evidence that the production structure of regions is not insignificant, but does certainly not entirely govern the innovativeness of regions, as in particular distinct local factors appear to affect innovativeness of firms. This implies that also the production 'milieu' component clearly affects innovativeness of regions. In other words, this calls for actions by local and regional governments to improve the quality of local business environment.

This analysis had a strong focus on links of firms in European cities with local universities, based upon specific labour market needs. Two factors which also appeared to influence the innovativeness of regions, i.e. local production networks (suppliers, subcontractors and customers) and local connectivity with larger (global) networks (telecommunication and transport links) have received much less attention. It is the interaction of the three factors from a knowledge perspective, which is an interesting field for further research, because it is largely open. The question then is whether the local labour market needs and production network needs are concerned with reduction of uncertainty using locally produced and released knowledge, or - via connectivity - using globally available knowledge (potentially in a specific niche). It would be interesting to scrutinize whether there is a difference between European cities in local self-containment of knowledge production, local conditions to insert global knowledge in the local economy, and the existence of a blend of local and blobal knowledge, and how this relates to the need of innovative firms for fast adjustment in view of risk and uncertainty. Thus, particularly the relationship between the local and global asks for attention, in terms of mutual dependency and cross-fertilisation. In addition, it is increasingly realised that knowledge networks - regarding type and geographical scale - may be different between different (young) sectors and even between product groups within sectors (Storper, 1996). Dependent on different demands for local knowledge and access to global knowledge, different urban policies need to be established in European cities.

Acknowledgements

This study was a part of a research project funded by the Academy of Finland. The authors wish to thank Tomaso Pompili and Peter Townroe for their assistance in collecting the data.

References

Amin, A. and N. Thrift (1994). Living in the Globe, in Amin, A. and N. Thrift (eds.) Globalization, Institutions, and Regional Development in Europe, Oxford University Press, Oxford, 1-22.

Baaijens, S. and P. Nijkamp (1997). Meta-Analytic Methods for Comparative and Exploratory Policy Research. Journal of Policy Modelling (forthcoming).

Boschma, R.A. (1994). Looking Through a Window of Locational Opportunity: A long-term spatial analysis of techno-industrial upheavals in Great Britain and Belgium. Thesis Poblishers, Amsterdam.

Bergh, van den J.C.J.M, K. Button, P. Nijkamp and G. Pepping (1997). Meta-Analysis for Meso Environmental Policy. Kluwer, Dordrecht.

Camagni, R. (1991). Local 'Milieu', Uncertainty and Innovation Networks: Towards a New Dynamic Theory of Economic Space, In R. Gamagni (ed.) Innovation Networks: Spatial Perspectives. Belhaven Press, London and New York, pp. 121-144.

Charler, D. and J. Howells (1992). Technology Transfer in Europe, Belhaven, London.

Davelaar, E.J. (1991). Regional Economic Analysis of Innovation and Incubation. Avebury, Aldershot, England.

Davelaar, E.J. and P. Nijkamp (1997). Spatial Dispersion of Technological Innovation: A Review, in Bertuglia, C.S., S. Lombardo and P. Nijkamp (ed.) Innovative Behaviour in Space & Time. Springer-Verlag, Berlin.

Dosi, G. (1988). The Nature of the Innovative Process, in G. Dosi et al. (eds.) Technical Change and Economic Theory. Printer Publishers, London and New York.

FAST (1992). The Future of Europand Cities: The Role of Science and Technology, Dossier no. 4, Commission of the European Communities, DG XII, Brussels.

Florax, R. (1992). The University: A Regional Booster, Avebury, Aldershot.

Geenhuizen, M. van, M. Damman and P. Nijkamp (1996a). The Local Environment as a Supportive Operator in Innovation Diffusion, Research Memorandum 1996-15, Dept. of Economics, Free University, Amsterdam.

Geenhuizen, M. van, and G.A. van der Knaap (1997). R&D and Regional Network Dynamics in the Dutch Pharmaceutical Industry, Journal of Economic and Social Geography, 88, 4, 307-370.

Geenhuizen, M. and P. Nijkamp (1996a). What Makes the Local Environment Important for High Tech Small Firms, in R. Oakey (ed.) New Technology-Based Firms in the 1990s. Vol I, Paul Chapman, London, 141-151.

Geenhuizen, M. and P. Nijkamp (1996b). Technology Transfer: How to Remove Obstacles in Advancing Employment Growth, in Kuklinski A. (ed.) Production of Knowledge and the Dignity of Science. Warsaw, Euroreg.

Geenhuizen, M. van, P. Nijkamp and H. Rijckenberg (1996b), Universities as key Actors in Knowledge-based Economic Growth, Reserach Memorandum 1996-14, Dept. of Economics, Free University, Amsterdam.

Gertler, M.S. (1995). "Being There": Proximity, Organization, and Culture in the Development and Adoption of Advanced Manufacturing Technologies. Economic Geography, 71, 1, pp. 1-26.

Gibbons, M. C. Limoge, H. Nowotny, S. Schwartzman, P. Scott and M Trow (1994). The Production of Knowledge: the Dynamics of Science and Research in Contemporary Societies, Sage, London.

Harrison, B., M.R. Kelley and J. Gant (1996). Innovative Firm Behavior and Local Milieu: Exploring the Intersection of Agglomeration, Firm Effects, and Technological Change. Economic Geography, 72, 3, pp. 233-258.

Kangasharju, A. and P. Nijkamp (1997). Innovation Dynamics in Space: Local Actors and Local Factors Discussion Papaer, Tinbergen Institute, Free University of Amsterdam, (forthcoming).

Kanter, R.M. (1995). World Class: Thriving Locally in a Global Market. Simon and Schustez, New York.

Kline, S.J. and N. Rosenberg (1987). An Overview of Innovation. In R. Landau et al. (eds.) The Positive Sum Strategy. National Academy Press, Washington, D.C.

Lambooy, J.G. (1996). Knowledge Production Organization and Agglomeration Economies, Research Paper, Economic-Geographical Institute, University of Amsterdam.

Love, J.H., B. Achcroft and S. Dunlop (1996). External Ownership, Corporate Structure and Product Innovation. Paper presented at 36th Congress of the European Regional Science Association, 26-30 August, 1996.

Ormrod, R.O. (1990). Local Context and Innovation Diffusion in a Well-Connected World. Economic Geography, 66, 2, pp. 109-122.

Ratti, R. (1991). Small and Medium-size Enterprises, Local Synergies and Spatial Cycles of Innovation, in R. Camagni (ed.) Innovation Networks: Spatial Perspectives. Belhaven Press, London and New York, pp. 71-88.

Storper, M. (1996). Innovation as Collective Action: Conventions, Products and Technologies, Industrial and Corporate Change, 5, 3, 731-790.

Theil, H. (1971). Principles of Econometrics. John Wiley, New York.

Vernon, R. (1966). International Investment and Institutional Trade in the Product Cycle. Quarterly Journal of Economics, 80, pp. 190-207.